Injection Kicker Ceramic Coating Considerations - SDH 7/31/01

- The primary requirement of coating is to provide low impedance at low-frequencies (resistive-wall):
  - ω_0 (longitudinal) and lowest $\omega = (n-Q)\omega_0$ (transverse)
  - $(Q_x, Q_y) = (6.3, 5.8)$ means 200 kHz
  - $(Q_x, Q_y) = (6.4, 6.3)$ means 600 kHz
  - Need to focus on impedance and place this object in the context of the impedance budget in order to know how to proceed!
- Consistent with eddy-current heating limitations
- Take 100W/m max power deposition from BNL thermal analysis
- Dimensions: 16cm ID, 6 chambers x 0.83m
- Kicker specifications: B = 0.1T (for 1.3 GeV),
- Power-supply spec is 200 μs linear ramping time

Eddy Current Estimation

- Assume uniform coated ceramic with film contact to end-flanges:
- Linear Field Ramp:

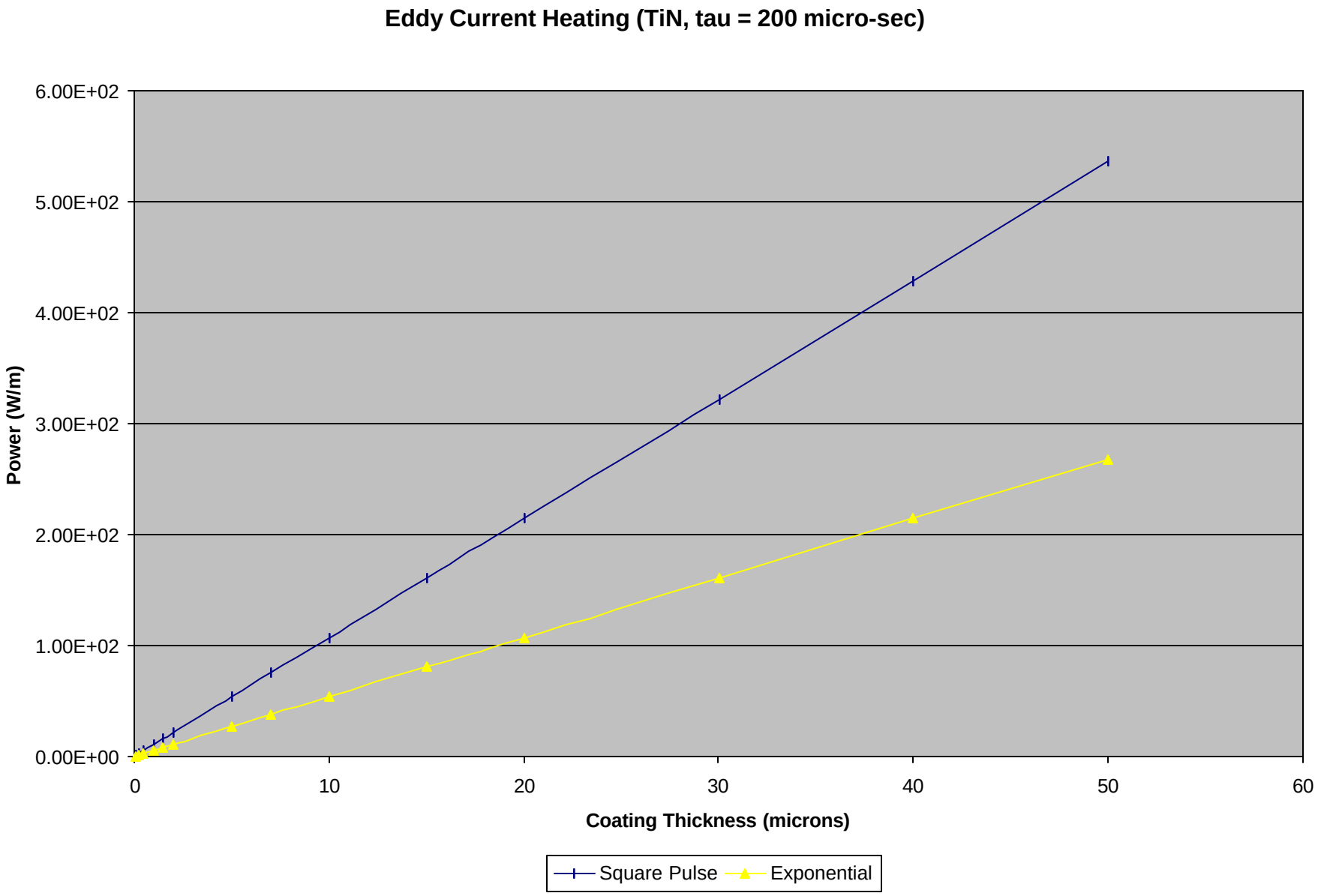
$$P = \frac{pB_0^2 r^3 lf}{R_s t} \qquad R_s = \frac{r}{d}$$

- Exponential Ramp:

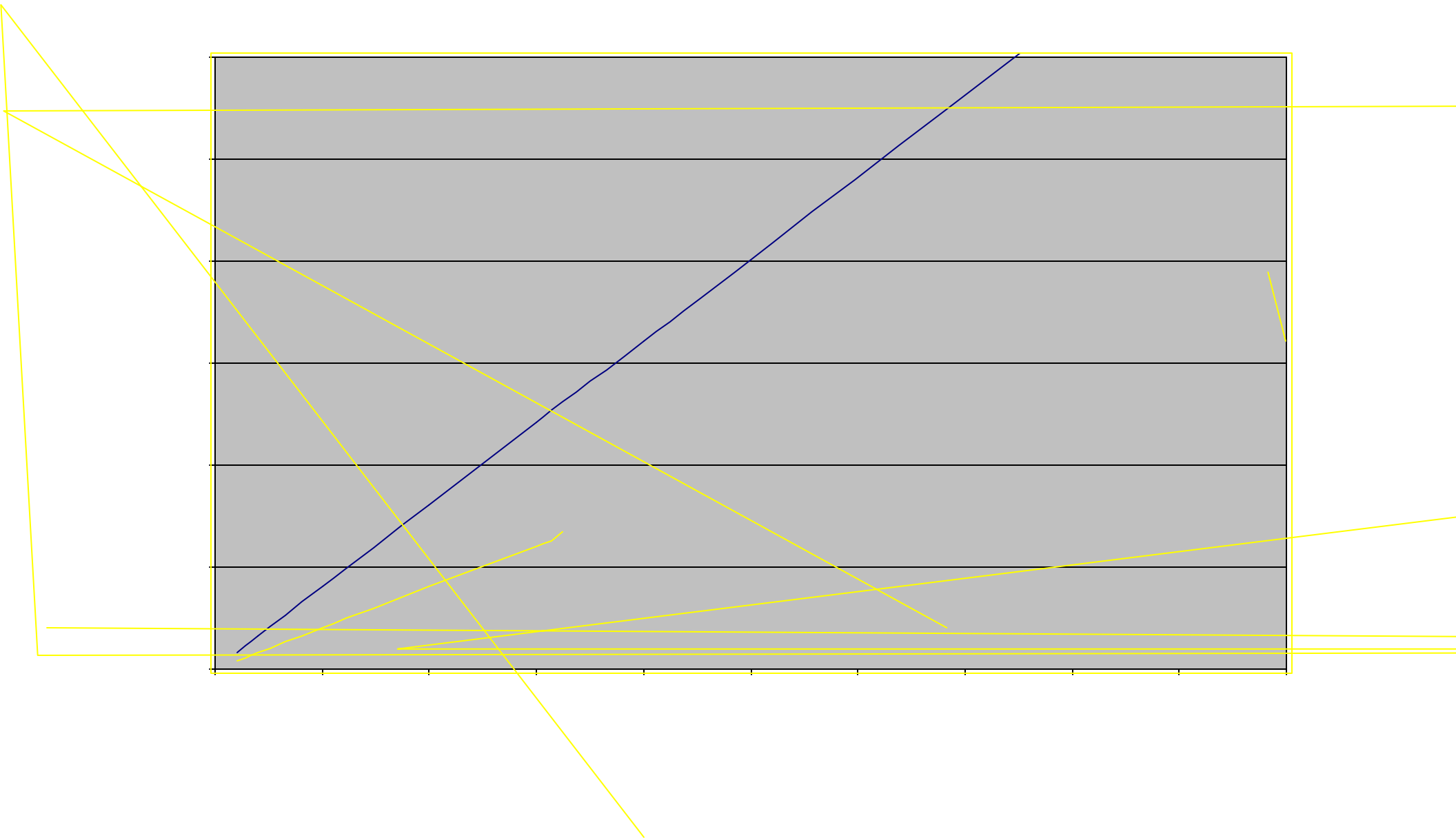
$$P = \frac{pB_0^2 r^3 lf}{2R_s t}$$

- For fixed magnetic field parameters, coating R_s (sheet-resistance) determines eddy current heating
- Local power-deposition is highest where eddy-current loop is largest (horizontal plane for $B=B_y$)
- BNL has done F.E. calculation of eddy-currents with 300 μs exponential pulse (agrees with analytic)

Eddy Current Heating – TiN



Eddy Current Heating - Gold



Impedance

- Skin-depth:

	200 kHz	1 MHz
Gold (3 μΩ-cm)	195 μm	87 μm
TiN (45 μΩ-cm)	754 μm	337 μm

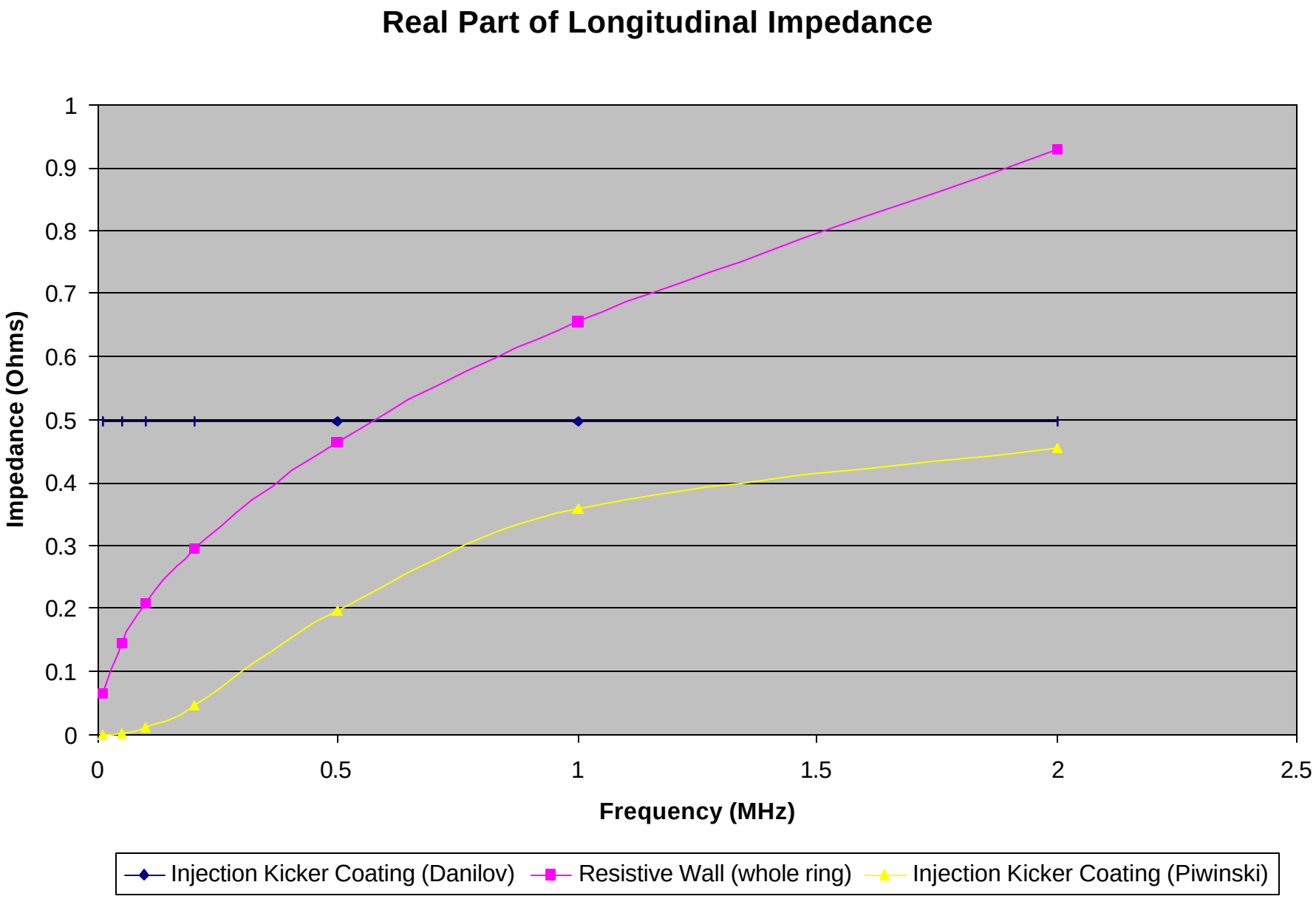
- We are in regime where thickness << skin depth.
- Slava Danilov finds all current runs through coating
- Longitudinal Impedance is simple DC resistance of the film:

$$Z_L = R = \frac{rl}{2prd} = \frac{R_s l}{2pr}$$

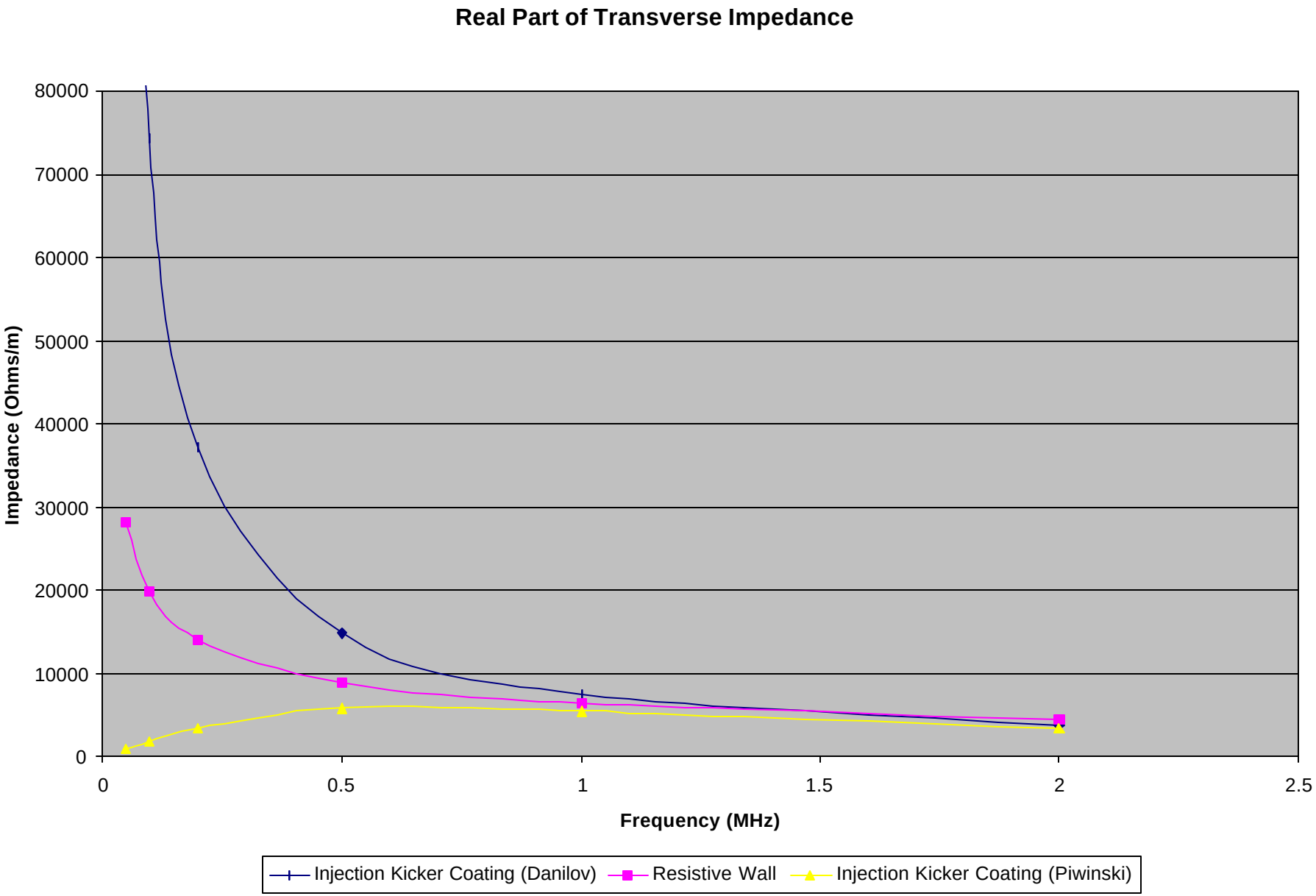
- Only sheet-resistance enters: For a given eddy-current heating, the impedance is determined and is independent of coating material:

$$Z_L = \frac{pB_0^2 r^3 lf}{tP_{eddy}} \frac{l}{2pr}$$

Longitudinal Impedance: 9 μm TiN



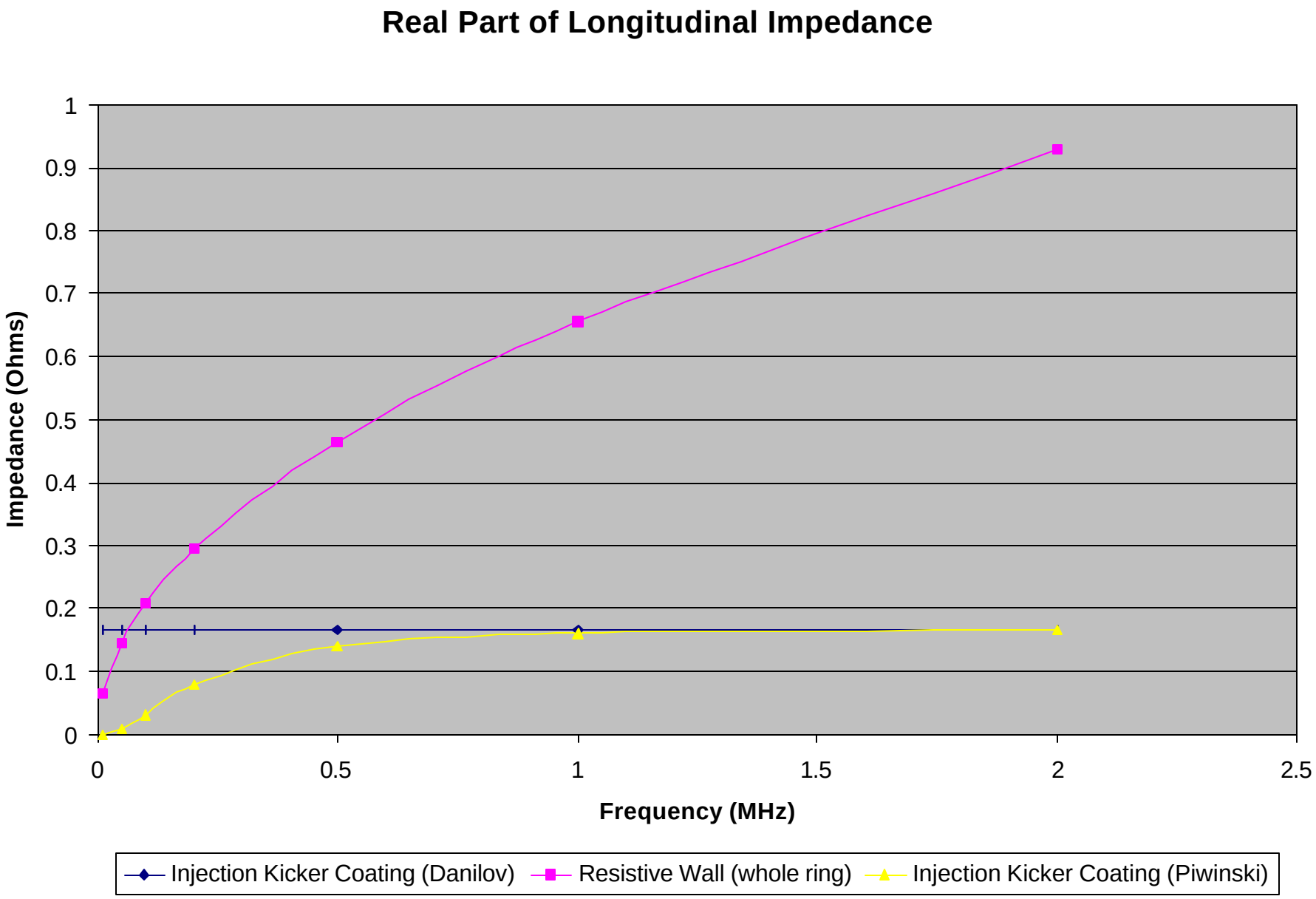
Transverse Impedance – 9 μm TiN



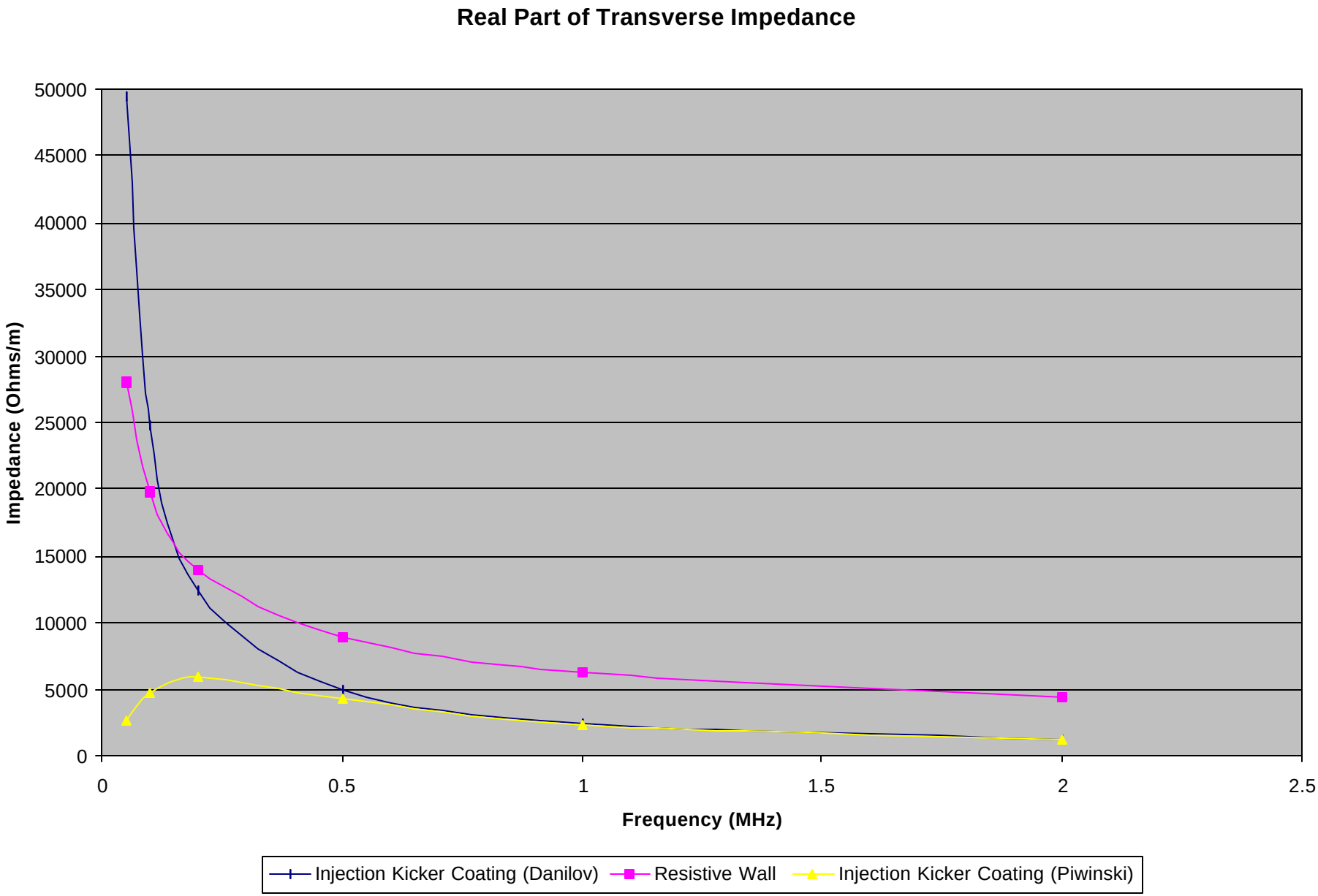
Options

- Evaluate this impedance to see if its dangerous (Danilov, Holmes..). It is.
- Relax the 200 μs linear field ramp specification
  - What if we restrict ourselves (forever) to τ = 300 μs exponential field pulse?
  - Then eddy current reduction allows coating thickness to be increased from
    - TiN: 9 μm to 27 μm
    - Gold: 0.6 μm to 1.8 μm
  - And impedances reduced by 1/3

Longitudinal Impedance – 27 μm TiN



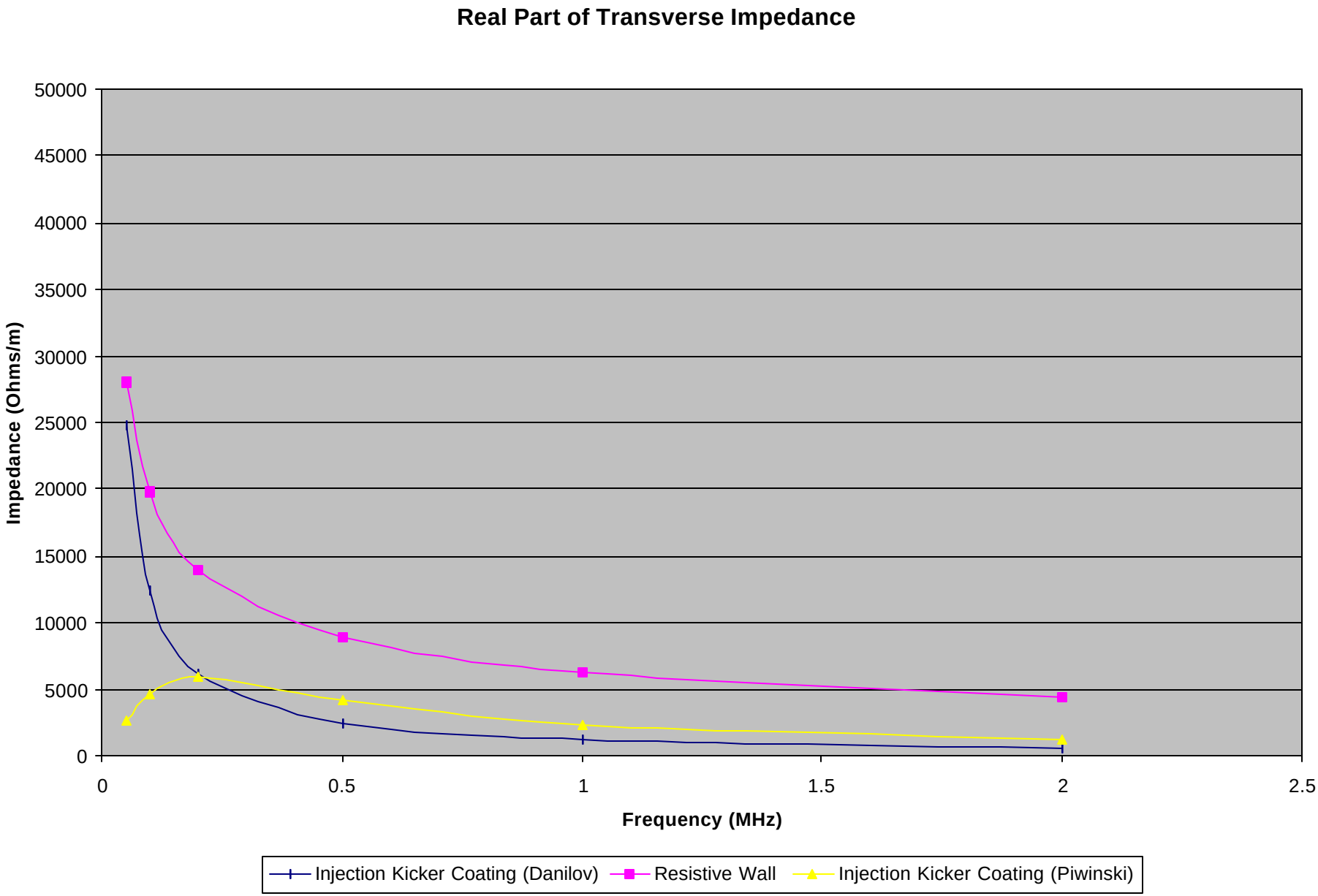
Transverse Impedance – 27 μm TiN



Options

- Take advantage of eddy-current heating distribution to make thick coating on top and bottom and thin on sides. Example: (see next slide)
  - 1.8 μm Gold has 100W/m eddy, R = 0.16 Ohms
  - 7.5 μm Gold ($0<\theta<45$) and 0.6 μm Gold ($45<\theta<90$) has 100W/m eddy and R = 0.074 Ohms
- Put thicker coating on middle chambers which have smaller kicker fields (with some loss in flexibility).
- Coat longitudinal thick gold stripes and lay thin TiN on top. These stripes must have high resistance to flanges (and each other) to avoid eddy currents. Detailed stripe design would be required with F.E. modeling of eddy currents.
- Use an external conductor to short the chamber flanges together (eddy currents, impedance?)

Thick Gold on Top and Bottom



Recommendation

- Do away with linear 200 μs field ramping requirement for eddy currents. Settle on 300 μs quasi-exponential time-dependent fields for painting.
- Avoid very thick TiN coating by adopting two-layer coating (TiN on Au) (Water cooled gold-rod with 1mm Au clad on SS ~7k$)
- Apply thick gold layer on top and bottom either with a movable shield or by installing shield
- Revisit eddy current estimation of this non-uniform coating using BNL machinery
- Apply thicker coating to middle chambers
- Investigate external conductors on coated chamber